UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
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AN INDEX FOR RATING THE AGRICULTURAL VALUE OF SOILS

R. EARL STORIE

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R. EARL STORIE[2]

INTRODUCTION

The growth and production of plants is dependent very largely upon the soil, and particularly the degree to which it presents conditions favorable for the extension and development of plant roots. On soil that is deep, pervious, relatively uniform in character, and that has fair water-retaining capacity, a very wide range of plants may grow vigorously. On soil with subsoil characteristics that retard the extension of plant roots, growth and development of the plants may likewise be retarded. If the subsoil is only moderately dense and root development only slightly hindered, the growth and production may be good, but if the density of the subsoil reaches that of a claypan, root penetration may be decidedly limited, and if the subsoil is cemented into a true hardpan, or underlaid by hard bedrock, penetration is definitely prevented.

These variations in the character of the soil are directly related to its origin, its mode of formation, and the age or stage of weathering. Recent alluvial deposits are generally deep and pervious, and the profile, or vertical section through the soil mass, shows no variations such as are developed with age. Older soils, which have been exposed to the weathering agents for very long periods of time, have subsoils that have become more dense, until finally they may reach the claypan or hardpan stage. Such soils, which are considered maturely weathered, have approached a condition of equilibrium with the factors that have determined the particular characteristics of their profiles.

The growth of plants on the soil is so closely related to these characteristics of the profile, and the chemical composition of the several horizons of the soil is likewise so closely related to the profile, that it appears possible to rate the soils with the profile characteristics as a base.

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2 Assistant Soil Technologist in the Experiment Station.

The index for rating soils as used herein is a numerical expression of the degree to which a particular soil presents conditions favorable for plant growth and crop production under good environmental conditions. In arriving at the relative index of soils three general factors are considered. These are (A) the character of the soil profile; (B) soil texture; and (C) other modifying factors, such as drainage, alkali, and other miscellaneous conditions. Each of these three factors is evaluated on the basis of 100 per cent for the most favorable or ideal condition, with limiting maximum and minimum ratings ascribed to conditions that are less favorable for plant growth.

The information set forth in the various soil-survey publications has been used in developing the index. For a discussion of the soil survey as a source of information, the reader is referred to the Appendix. In studying, mapping, and classifying soils, the character and degree of development of the soil profile, the reaction of the soil mass, the color, the physical composition of the various horizons, the mode of formation and composition of the parent material, the drainage and surface relief, the alkali content, natural cover, etc., are considered in detail.

In arriving at the ratings the experience and judgment of the men engaged in soil-survey work in California has been called upon, and the ratings express the results of their collective studies of the relations of these several conditions of the soil to the growth and production of plants. Obviously, such ratings cannot be final and infallible and may be changed as experience with the use of the soil index indicates.

The index is based on soil conditions alone independent of other physical or economic factors which might determine the desirability of growing certain plants in a given location; hence it cannot be regarded as by itself an index for land evaluation. In the latter, other factors, such as variations in climate, availability of water for irrigation, facilities for transportation and markets, social conditions, and the like, must be included.

Although the soil is only one of the many factors that determine the value of any given area of land surface, it is one that does not readily change and that cannot be materially modified without the expenditure of much effort. Its quality or value is one of the more stable elements that determine *land value,* and an index for rating soils should serve to simplify the work of land classification and evaluation. Other factors, such as the climate, or the quality, quantity, and availability of water for irrigation are likewise natural factors, more or less stable in character, that may be rated in a similar manner, but some physical, economic, and social factors may be too variable or too readily changed to permit of such treatment. Studies of these other factors that influence

or modify land values may show the possibilities of developing indexes for groups of these factors, and by integrating these several indexes, a positive numerical expression of the relative value of any portion of the land surface may result.

METHOD OF RATING

In most endeavors to rate soils on a comparative basis the "score card" method has been used, and the rating determined by *adding* the points credited to each of the soil characteristics or modifying factors. In the index method here presented the rating is obtained by *multiplying* the three factors, A times B times C, thus permitting any one of these to dominate or control the final rating. As an example, a soil may have an excellent profile condition warranting a rating of 100 per cent for factor A, excellent surface-soil conditions giving 100 per cent for factor B, but a bad alkali accumulation that would give a rating of 10 per cent for factor C. Multiplying these three percentage ratings—$A \times B \times C$—gives 10 per cent as the index for this soil. The severe alkali accumulation would dominate the quality of this soil, rendering it wholly unproductive for plants and would justify the index of 10 for that soil. On the score-card basis, with possibly 20 or 25 points ascribed to alkali or similar conditions, its worst rating could be only 75 or 80.

The characteristics or conditions included under each of these factors is described in the following chapter, and their bearing on the quality of the soil is discussed.

FACTOR A: CHARACTER OF SOIL PROFILE

Factor A evaluates all the characteristics of the soil profile except the texture of the surface soils. These characteristics, which are determined by the kind of parent material, its mode of formation or accumulation, and the age or degree of modification of the soil material by the weathering agencies of climate, supplemented by vegetation and opposed by erosion and deposition, serve to separate the soils into groups of related individuals that are classed as soil series.

The suitability of soils for plant growth is dependent to a very large extent on the profile characteristics that differentiate the soil series. A series may be defined as "a group of soils having the same character of profile; that is, the same range in color, structure, and general sequence of soil and subsoil horizons, the same general types of relief and drainage, and a common or similar origin and mode of formation."[3] The

[3] Shaw, C. F. A glossary of soil terms. American Soil Survey Association Bul. 9:28–58. 1927.

name of the series implies all the characteristics used to define the soil type except that of surface texture.

For factor A of this index, the soil series of California have been placed in six general groups and a rating given soils of these groups. In each group are series having similar modes of formation, similar sequence of soil and subsoil horizons (i. e., layers), a comparable age, and the same types of relief. The soil series of California officially recognized by the Bureau of Chemistry and Soils of the United States Department of Agriculture and the California Agricultural Experiment Station are listed alphabetically in table 1 with their position in the six groups on the basis of factor A and with certain of their profile characteristics indicated.

The profile characteristics and inclusive ratings for each group under factor A are given in table 2.

Secondary[4] soils are placed in groups I, II, III, and IV; strongly weathered secondary and primary[5] soils having dense clay subsoils developed on consolidated material in group V; and primary soils in group VI. In the following sections characteristics of the soils in each group are described and the profile rating of each explained.

Where soil surveys have been made, the necessary information for this grouping can be obtained from the reports and maps, but if a survey has not been made, then a field examination of the area to be rated is needed in order to determine the profile characteristics.

GROUP I, UNWEATHERED OR ONLY SLIGHTLY WEATHERED SECONDARY SOILS (RECENT OR YOUNG SOILS)

When they have been transported by water, the unweathered secondary soils are commonly referred to as the alluvial, stream-bottom, floodplain, alluvial-fan, or recent, transported soils. Group I also includes soils deposited or reworked by the action of winds, commonly classed as aeolian or wind-modified soils.

Soils of this group are characteristically more than 6 feet deep and consist of a mass of soil material which has not been modified to any extent by the action of weathering forces, which ultimately bring about a change in the general character of the soil profile. It is because of this that they are spoken of as unweathered soils, in contrast to the moderately weathered soils of group II.

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[4] Secondary soils are those formed by the accumulation and weathering of transported materials, originating from previously existing soils and from rock debris, and are often referred to as alluvial, aeolian, or glacial soils, according to the agency which transported them.

[5] Primary soils are those formed by the disintegration and decomposition of rocks in place and the weathering of the resultant debris to true soil.

TABLE 1

SOIL SERIES OF CALIFORNIA LISTED ALPHABETICALLY SHOWING THEIR POSITIONS IN THE SIX GROUPS ON THE BASIS OF FACTOR A, AND ALSO SHOWING THE COLOR* OF THE SURFACE SOIL AND THE SOIL REACTION

Series	Group	Color of surface soil	General reaction
Adelanto	III	Grayish brown	Calcareous subsoils
Agate	V	Brown	Calcareous substratum
Agueda	I	Dark brownish gray	Calcareous throughout
Aiken	VI	Red	Moderately acid
Alamo	IV	Dark gray	Neutral
Aliso	III	Reddish brown	Calcareous subsoils
Altamont	VI	Brown	Calcareous subsoils
Alviso	I	Dark gray	Usually saline
Anderson	I	Yellowish brown	Neutral
Anita	II	Dark brown	Neutral
Antelope	V	Dark gray	Neutral
Antioch	III	Dark brown	Calcareous subsoils
Arbuckle	I	Grayish brown	Neutral
Arnold	VI	Brownish gray	Moderately acid
Arroyo Seco	I	Light brown	Neutral
Atascadero	V	Dark brownish gray	Slightly acid
Ayar	VI	Brown	Calcareous throughout
Ballard	II	Brown	Neutral
Barron	II	Grayish brown	Neutral
Bayside	I	Grayish brown	Moderately acid
Baywood	I	Dark brown	Moderately acid
Bear	I	Reddish brown	Neutral
Bellevista	IV	Light gray	Calcareous throughout
Bieber	V	Dark brown	Neutral
Bishop	I	Dark brownish gray	Calcareous throughout
Botella	I	Dark brownish gray	Neutral
Buntingville	II	Dark grayish brown	Calcareous subsoils
Butte	VI	Brownish gray	Neutral
Cachuma	III	Reddish brown	Neutral
Cajon	I	Light brownish gray	Calcareous throughout
Canby	V	Light gray	Calcareous subsoils
Capay	III	Dark grayish brown	Calcareous subsoils
Carlsbad	VI	Brown	Slightly acid
Carrizo	I	Light gray	Calcareous throughout
Carson	I	Dark gray	Calcareous subsoils
Cayucos	VI	Dark gray to black	Moderately acid..
Centerville	III	Chocolate brown	Calcareous subsoils
Chamise	V	Dark grayish brown	Moderately acid
Chino	II	Dark gray	Calcareous subsoils
Chualar	II	Dark brown	Neutral
Churchill	IV	Grayish brown	Calcareous throughout
Clear Lake	I	Dark gray to black	Calcareous subsoils
Climax	VI	Dark gray to black	Neutral
Coachella	I	Gray	Calcareous throughout
Cole	II	Dark grayish brown	Slightly acid
Columbia	I	Light grayish brown	Neutral
Commatti	II	Gray	Calcareous subsoils
Conejo	I	Dark gray to black	Neutral
Contra Costa	VI	Reddish brown	Neutral

* Color, one of the most obvious of the many soil characteristics, is so closely correlated with the conditions under which the soil has been formed that it often gives considerable information concerning the other characteristics of the soil, such as the organic matter content.

TABLE 1—*(Continued)*

Series	Group	Color of surface soil	General reaction
Coquille	I	Grayish brown, mottled	Acid; saline
Corning	III	Light red	Neutral
Corralitos	II	Brown	Slightly acid
Cuyama	II	Brownish gray	Calcareous throughout
Danville	I	Dark brown	Neutral
Daulton	VI	Reddish brown	Neutral
Delaney	I	Light brownish gray	Neutral
Delano	II	Light reddish brown	Calcareous subsoils
Delhi	I	Light brown	Neutral
Denverton	III	Dark brown	Calcareous subsoils
Diablo	VI	Dark gray to black	Calcareous subsoils
Diamond Springs	VI	Grayish yellow	Slightly acid
Docas	II	Brownish gray	Calcareous throughout
Domino	IV	Light brownish gray	Calcareous throughout
Dublin	I	Dark gray to black	Neutral
Ducor	II	Dark chocolate brown	Calcareous subsoils
Dunnigan	III	Brownish gray	Calcareous subsoils
Egbert	I	Dark gray	Moderately acid
Elder	I	Dark brownish gray	Calcareous subsoils
Elkhorn	II	Brown	Slightly acid
Elna	IV	Light gray	Calcareous throughout
Empire	III	Reddish brown	Strongly acid
Encina	VI	Dark brown	Slightly acid
Escondido	VI	Yellowish brown	Neutral
Esparto	II	Light brown	Slightly acid
Exeter	III	Reddish brown	Neutral
Fallbrook	VI	Reddish brown	Neutral
Fancher	IV	Reddish brown	Neutral
Farwell	I	Light chocolate brown	Calcareous subsoils
Feather	I	Brown	Neutral
Ferndale	I	Brownish gray	Moderately acid
Foster	I	Dark brownish gray	Calcareous throughout
Fresno	IV	Brownish gray	Calcareous; alkaline
Fullerton	II	Brown	Neutral
Galveston	I	Dark gray	Usually saline
Gleason	VI	Dark brown	Neutral
Garey	II	Light reddish brown	Moderately acid
Gazelle	IV	Dark brownish gray	Calcareous throughout
Gila	I	Light purplish brown	Calcareous throughout
Gloria	IV	Brownish red	Neutral
Goldridge	VI	Yellowish gray	Moderately acid
Gould	V	Reddish brown	Neutral
Greenfield	I	Brown	Neutral
Gridley	III	Brown	Neutral
Hames	III	Brown	Slightly acid
Hanford	I	Light brown	Neutral
Hartley	III	Light brownish red	Neutral
Hesperia	I	Light brown	Calcareous subsoils
Holcomb	III	Light brown	Moderately acid
Holland	VI	Brown	Slightly acid
Holtville	I	Light purplish gray	Calcareous throughout
Honcut	I	Reddish brown	Neutral
Hovey	II	Dark gray to black	Calcareous subsoils
Huerhuero	III	Light grayish brown	Calcareous subsoils
Hugo	VI	Yellowish brown	Moderately acid
Imperial	I	Light purplish gray	Calcareous, alkaline
Indio	I	Brownish gray	Calcareous throughout

TABLE 1—*(Continued)*

Series	Group	Color of surface soil	General reaction
Johnsonville	II	Brown	Calcareous subsoils
Keefers	III	Brownish red	Slightly acid
Kettleman	VI	Gray	Calcareous throughout
Kimball	III	Brownish red	Neutral
Kirkwood	III	Dark gray	Neutral
Klamath	III	Dark gray	Neutral
Kneeland	V	Dark grayish brown	Moderately acid
Konokti	VI	Brown	Slightly acid
Laguna	I	Light brownish gray	Neutral
Lahontan	II	Light gray	Calcareous; alkaline
Landlow	V	Brown to dark brown	Calcareous subsoils
Las Flores	V	Light gray	Slightly acid
Las Posas	VI	Brownish red	Neutral
Lassen	VI	Dark brown	Calcareous subsoils
Lewis	III	Brownish gray	Usually alkaline
Lindsey	II	Dark gray	Calcareous subsoils
Linne	VI	Dark brownish gray	Calcareous throughout
Livermore	II	Dark grayish brown	Neutral
Lockwood	III	Grayish brown	Neutral
Los Angeles	VI	Light brown	Calcareous subsoils
Los Osos	VI	Dark brown	Moderately acid
Lynndyl	II	Light grayish brown	Calcareous throughout
Madera	IV	Brown	Neutral
Manzanita	III	Brownish red	Moderately acid
Marcuse	III	Dark gray	Usually alkaline
Maricopa	II	Reddish brown	Neutral
Marina	I	Brown	Slightly acid
Mariposa	VI	Brownish yellow	Moderately acid
Marvin	II	Light brown	Calcareous subsoils
Marysville	IV	Reddish brown	Neutral
Maywood	I	Yellowish brown	Neutral
McClusky	III	Dark grayish brown	Moderately acid
Media	VI	Brown	Neutral
Melbourne	VI	Brown	Moderately acid
Meloland	I	Light brownish gray	Calcareous throughout
Merced	III	Dark gray to black	Calcareous subsoils
Merriam	III	Light reddish brown	Calcareous subsoils
Metz	I	Light brown	Calcareous throughout
Mocho	I	Brown	Calcareous throughout
Modoc	II	Dark brown	Neutral
Mojave	III	Reddish brown	Calcareous throughout
Mono	IV	Light brownish gray	Calcareous throughout
Monserate	V	Brown	Calcareous subsoils
Montague	IV	Dark grayish brown	Calcareous subsoils
Monterey	VI	Reddish brown	Moderately acid
Montezuma	III	Dark gray to black	Calcareous subsoils
Moro Cojo	VI	Reddish brown	Moderately acid
Nacimiento	VI	Brownish gray	Calcareous throughout
Niland	II	Light brownish gray	Calcareous; alkaline
Nord	I	Grayish brown	Calcareous throughout
Norman	III	Dark brown	Often alkaline
Oakdale	I	Grayish brown	Neutral
Oakley	I	Light brown	Slightly acid
Ojai	III	Pale yellow	Neutral
Olcott	III	Brown	Neutral
Olivenhain	V	Light brown	Slightly acid
Olympic	VI	Dark brown	Moderately acid

TABLE 1—(Continued)

Series	Group	Color of surface soil	General reaction
Orland	II	Light grayish brown	Neutral
Oxnard	I	Brown	Calcareous subsoils
Pajaro	I	Brown	Neutral
Panoche	I	Brownish gray	Calcareous throughout
Pentz	VI	Dark grayish brown	Neutral
Pinole	III	Yellowish brown	Neutral
Pit	I	Dark gray to black	Neutral
Placentia	III	Brownish red	Neutral
Pleasanton	II	Brown	Neutral
Pond	II	Brownish gray	Calcareous; alkaline
Poplar	II	Light brown	Neutral
Porterville	II	Chocolate brown	Calcareous subsoils
Preston	I	Light grayish brown	Slightly calcareous
Ramada	I	Light yellowish brown	Neutral
Ramona	II	Reddish brown	Neutral
Redding	IV	Brownish red	Strongly acid
Rhonerville	II	Dark brownish gray	Strongly acid
Rincon	II	Brown	Neutral
Rocklyn	IV	Brownish red	Slightly acid
Rosamond	II	Light grayish brown	Calcareous throughout
Rositas	I	Light brownish gray	Calcareous throughout
Sacramento	II	Dark gray to black	Slightly calcareous subsoils
Salinas	II	Dark brownish gray	Calcareous subsoils
Salsipuedes	II	Dark brown	Slightly acid
San Gabriel	I	Light brown	Neutral
San Joaquin	IV	Brownish red	Slightly acid
San Marcos	II	Dark brownish gray	Calcareous subsoils
San Ysidro	II	Brownish gray	Neutral
Santa Cruz	VI	Reddish brown	Moderately acid
Santa Lucia	VI	Dark grayish brown	Neutral
Santa Rita	II	Grayish brown	Calcareous throughout
Santa Ynez	III	Dark grayish brown	Neutral
Santiago	II	Dark gray	Calcareous subsoils
Shasta	II	Light brownish gray	Neutral
Shedd	VI	Gray	Calcareous throughout
Sheridan	VI	Dark gray	Neutral
Sierra	VI	Brownish red	Moderately acid
Siskiyou	VI	Brownish gray	Neutral
Sites	VI	Brownish red	Moderately acid
Solano	III	Dark brownish gray	Calcareous subsoils
Soledad	II	Brown	Neutral
Sorrento	I	Light brown	Calcareous subsoils
Stacy	I	Light brown	Calcareous throughout
Standish	V	Grayish brown	Calcareous throughout
Stockpen	III	Light gray	Calcareous subsoils
Stockton	V	Dark gray to black	Calcareous subsoils
Sunol	II	Reddish brown	Neutral
Sunrise	IV	Light reddish brown	Calcareous throughout
Superstition	I	Gray	Calcareous throughout
Surprise	I	Dark brown	Neutral
Sutter	I	Light brownish gray	Neutral
Tangair	IV	Brownish gray	Moderately acid
Tassajero	I	Brown	Neutral
Tehama	II	Light yellowish brown	Neutral
Tierra	V	Dark grayish brown	Moderately acid
Tijeras	V	Light reddish brown	Calcareous throughout
Tujunga	I	Light brownish gray	Neutral

TABLE 1—*(Concluded)*

Series	Group	Color of surface soil	General reaction
Tulare	II	Light gray	Calcareous throughout
Tuscan	V	Brownish red	Neutral
Ulmar	V	Grayish brown	Calcareous subsoils
Underwood	VI	Reddish brown	Calcareous subsoils
Vallecitos	VI	Reddish brown	Neutral
Vina	I	Light chocolate brown	Neutral
Vista	VI	Brown	Neutral
Wapato	I	Brown, mottled	Strongly acid
Watsonville	VI	Dark brown	Moderately acid
Westport	II	Dark brownish gray	Moderately acid
Whitney	VI	Reddish brown	Neutral
Willits	II	Grayish brown	Moderately acid
Willows	I	Reddish brown	Neutral
Woodrow	I	Brownish gray	Calcareous; alkaline
Wyman	II	Reddish brown	Neutral
Yolo	I	Brown	Neutral
Ysidora	VI	Reddish brown	Neutral
Zaca	VI	Dark gray to black	Calcareous throughout

TABLE 2

RATING OF SOILS ON THE BASIS OF PROFILE CHARACTERISTICS

Group	Group number	Description	Surface relief	Profile rating (factor A) in per cent
Unweathered or slightly weathered secondary	I	Loose and friable material 6 feet or more deep	Flat or gently sloping	95–100
Moderately weathered secondary soils	II	Deep but have compact subsoils and slight to moderate accumulation of clay	Terraces, benches or valley floors	80–95
Strongly weathered secondary soils	III	Dense clay subsoils, loose unconsolidated parent material	Terraces	40–80
Maturely weathered secondary soils	IV	Hardpan soils, often have fairly dense clay subsoils	Flat terraces, valley floors, often hogwallow surface	5–60
Strongly weathered soils having dense clay subsoils, developed on consolidated material	V	Coastal plain soils	High eroded terraces	20–40
Primary soils (residual)	VI	Formed in place from decomposition and disintegration of underlying bedrock	Hilly, rolling or mountainous	20–70

The most valuable agricultural soils of California fall in this group; they occur on the flood plains and alluvial fans of many of the California streams. They are especially valuable for orchards, vegetables, and deep-rooted field crops. Yields on many of the medium-textured alluvial soils have remained consistently high for a long period without recourse to fertilization. The crop yields are consistently higher than on soils of the other groups. These soils, providing conditions favorable for the growth of almost any crop plants, have been given a factor-A rating of 95 to 100 per cent.

TYPE Yolo fine sandy loam LOCATION One mile southwest of Davis, Calif.
RELIEF Alluvial fan ELEVATION 50 feet DRAINAGE Well drained
RAINFALL 18 inches NATIVE VEGETATION Grasses USE Wide use.
ORIGIN Alluvial from sedimentary rock sources DEVELOPMENT OF PROFILE Recent soil
REMARKS Profile rating of 100.

PROFILE	COLOR	TEXTURE	STRUCTURE	CONSISTENCE AND DENSITY	REACTION	MISCELLANEOUS ROOTS, STONES, CONCRETIONS, PERMEABILITY, ETC.
0  12	Brown to light brown	fine sandy loam	granular	loose and friable	neutral 7.0	considerable organic material and roots
24 36 48 60	light brown	variable textured	structureless	friable	neutral 7.0	easily penetrated by roots and moisture

Fig. 1.—Soil description and profile of Yolo fine sandy loam. This type of form is of use in reporting and showing the characteristics of a soil by horizons.

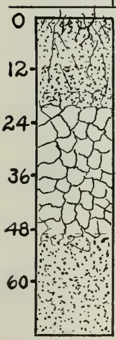
Variation in texture of the surface soils is rated under factor B and discussed in a separate section. Any conditions unfavorable to plant growth, such as gravelly subsoil layers, injurious amounts of alkali, high acidity, or poor drainage conditions that may occur are rated under factor C.

The Hanford, Yolo, Columbia, and Honcut are extensively developed soil series of this group. The fact that some of the best crop yields of the state are secured on these soils indicates the soundness of the high rating given them. Figure 1 gives a typical profile of a Yolo fine sandy loam which serves to illustrate the general depth and pervious nature of the profiles of soils in group I.

GROUP II, MODERATELY WEATHERED SECONDARY SOILS (IMMATURE SECONDARY SOILS)

Group II consists of water-laid or wind-laid deposits which have been subjected to weathering for a sufficient period to develop subsoil characteristics very distinct from those of the recent or unweathered group. These have profiles with clearly evident clay accumulations in the moderately compact subsoil layers, while many of the soils also have accumulations of lime in the subsoil. Subsoils are permeable to moisture and roots, although not to the same degree as the younger soils of group I.

TYPE Ramona sandy loam LOCATION El Cajon Valley - San Diego County
RELIEF Sloping terrace ELEVATION 500 feet DRAINAGE Well drained
RAINFALL 12 inches NATIVE VEGETATION Grass - brush USE Wide use.
ORIGIN Secondary from granite DEVELOPMENT OF PROFILE Immaturely weathered
REMARKS Occupies a terrace slightly higher in elevation than the recent alluvial soils. Profile rating of 90.



PROFILE	COLOR	TEXTURE	STRUCTURE	CONSISTENCE AND DENSITY	REACTION	MISCELLANEOUS ROOTS, STONES, CONCRETIONS, PERMEABILITY, ETC.
0–12	Brown	sandy loam	medium granular	dries out fairly hard	neutral 7.0	permeable
12–24	Brown to reddish brown	gritty loam	coarse granular	slightly compact. fairly hard when dry.	neutral 7.0	permeable
24–36–48	reddish brown	sandy clay loam	irregular shaped clods when broken up dry.	moderately compact	neutral 7.0 - 7.3	considerable colloidal staining on surface of clods. permeability of moisture somewhat retarded.
48–60	pale reddish brown	sandy loam	amorphous	slightly compact.	neutral 7.0	

Fig. 2.—Profile description of Ramona sandy loam, San Diego County, California, illustrative of the general characteristics of the soils in group II (moderately weathered secondary soils), having compact subsoil layers with clay accumulations.

This is evidenced by the somewhat slower penetration of irrigation water. The parent material below the subsoil is usually permeable to a depth of 6 feet or more. These soils usually occur on smooth terraces and mesas, lower benches, and in some cases on typical alluvial-fan surfaces, usually being slightly higher in elevation than those of group I. Many of the soil series in this group occur on terraces which have been slightly eroded so that the topography is somewhat irregular, especially on the borders.

These are good soils, although of less value than those of group I, since they are older, have a moderate subsoil compaction and accumulation of clay, which retards the penetration of moisture, and may have a more

irregular surface, which lessens their value for irrigated crops. They are given a factor-A rating of 80–95 per cent.

Soils of the Ramona series are the best known in this group. A typical profile description of Ramona sandy loam is given in figure 2.

GROUP III, STRONGLY WEATHERED SECONDARY SOILS WITH DENSE CLAY SUBSOILS (SEMIMATURE SECONDARY SOILS)

The soils of group III are characterized by a very heavy, dense, plastic clay subsoil layer that breaks up when dry into very hard dense structural aggregates. These are semimaturely weathered soils. They are of

TYPE Antioch fine sandy loam LOCATION Eastern Solano County
RELIEF Flat terrace ELEVATION 40 feet DRAINAGE Subdrainage restricted
RAINFALL 18 inches NATIVE VEGETATION Grass USE Pasture
ORIGIN Mixed material DEVELOPMENT OF PROFILE Semimature
REMARKS Profile rating of 60

PROFILE	COLOR	TEXTURE	STRUCTURE	CONSISTENCE AND DENSITY	REACTION	MISCELLANEOUS ROOTS, STONES, CONCRETIONS, PERMEABILITY, ETC.
0–12–	Dull grayish brown	fine sandy loam	slightly granular	friable, loose	slightly acid pH 6.2	fairly well filled with roots.
24–	light gray	sandy loam	single grained	loose	pH 6.5	
36–	Dark grayish brown	clay	breaks up into columns when dry	very compact	neutral to slightly basic	colloidal glazing
48–	Dark grayish brown	clay loam or clay	cubical when dry	compact	Basic. Calcareous	lime occurs in nodules and seams
60–	Yellowish brown	loam	cloddy when broken	fairly compact	neutral to slightly basic	

Fig. 3.—Profile description of Antioch fine sandy loam from Solano County, California; claypan soil of group III.

alluvial or marine origin, but have been materially changed in chemical and physical make-up since they were deposited. All have a leached surface usually of sandy texture, low in available plant food, and normally moderately acid in reaction. There is usually an abrupt change from the sandier surface layers to the heavy, dense clay subsoils. The downward movement of water is markedly retarded and the soils become temporarily water-logged after heavy rains. The heavy subsoils are underlaid by pervious parent materials penetrable by roots and water. In some cases these parent materials are loose soil, while in others they are fairly compact, but in all cases they are penetrable to a depth of 6 feet or more.

These soils occupy terraces or benches which are often somewhat eroded. They are of common occurrence in most of the California valleys and along the coast line of central and southern California.

Their value is limited by the heavy subsoil layer and often to some extent by the eroded surface, which makes them difficult to irrigate and cultivate. They are given a rating of 40–80 per cent. Within these limits the rating will depend on the depth to the clay layer and the general surface conditions. Soils occurring under higher rainfall, such as the

Fig. 4.—Profile of San Joaquin sandy loam (hardpan soil, group IV), San Joaquin Valley, California. The hardpan layer is about 2 feet thick, with about 3 feet of soil material overlying the hardpan. (Photograph by C. F. Shaw.)

Antioch series, have surface soils as much as 20 to 24 inches in thickness, while the southern California soils of similar character (such as the Huerhuero series), but located where the rainfall is much less, have much shallower surface soils. Figure 3 gives details of a profile of the Antioch fine sandy loam located near Fairfield. This soil is given a higher rating than the Huerhuero because of its depth of surface soil and the level surface of the terrace on which it occurs.

GROUP IV, MATURELY WEATHERED SECONDARY SOILS WITH HARDPAN

The soils with hardpan appear to have reached a mature age or stage of weathering, and are characterized by the cemented, rock-like subsoil horizon (fig. 4) that has been formed as a direct result of the soil-weathering process. True hardpans do not soften when saturated with

water, thus being distinguished from certain dense clay subsoils, which are often erroneously referred to as hardpan layers.

True hardpan soils occur under arid or semiarid climatic conditions, and the depth to the hardpan layer is usually closely correlated with the depth of the annual penetration of rainfall. A dense clay layer normally lies just above the hardpan. Where the hardpan is continuous and unbroken, drainage conditions are poor and the surface soil becomes saturated after heavy rains. They usually occur on sloping terraces or on valley floors and often have a "hogwallow" surface of small mounds and depressions (fig. 5). Some areas have suffered considerable erosion.

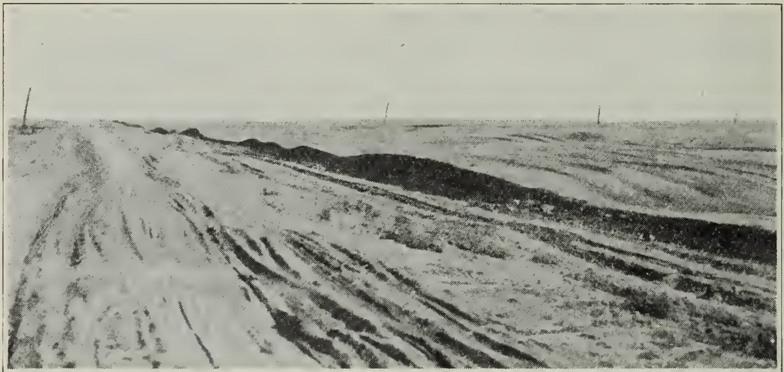


Fig. 5.—Natural mounds or "hogwallow" surface of San Joaquin sandy loam, Kern County, California. (Photograph by C. F. Shaw.)

The largest areas of hardpan soils lie in the Great Valley of California, especially in the San Joaquin. They are also scattered throughout the valleys of southern California. They occupy a total of over three million acres in the state.

Considerable discussion has developed over the subject of the utilization of hardpan soils and the extent to which the undesirable features, such as the limited depth of the soil material overlying the hardpan and the thickness and hardness of the hardpan, may reduce the value of such soils. The rooting zone of plants is limited when the hardpan is close to the surface. The moisture capacity is limited by the shallow depth of soil above the hardpan; irrigation water must be applied frequently and in small amounts, or saturation and poor drainage will result; and other difficulties arise owing to the limited mass of soil material. The organic content of hardpan soils is usually low, and the clay fractions of such character that the soils have a tendency to bake hard on drying, thus rendering them more difficult to handle. The undulating hogwallow surface configuration of such lands also renders them difficult to

prepare for irrigation. When they are leveled, it is noted that crops respond better in the filled places than they do on the areas where soil has been removed.

The following ratings are based on the depth to hardpan:

	Rating, in per cent
Hardpan less than 1 foot	5–10
1 to 2 feet	10–20
2 to 3 feet	20–30
3 to 4 feet	30–40
4 to 6 feet	40–60

These figures should be raised in certain instances where the hardpan is soft or broken or occurs in thin plates. A typical profile of San Joaquin sandy loam, a red "iron" hardpan soil, is given in figure 6.

TYPE San Joaquin sandy loam LOCATION Near Chowchilla – San Joaquin Valley
RELIEF Sloping terrace ELEVATION 250 feet DRAINAGE Subdrainage restricted
RAINFALL 11 inches NATIVE VEGETATION Grass USE Pasture
ORIGIN Secondary from granite DEVELOPMENT OF PROFILE Maturely weathered
REMARKS "Red iron" hardpan soil
Profile rating of 25.

PROFILE	COLOR	TEXTURE	STRUCTURE	CONSISTENCE AND DENSITY	REACTION	MISCELLANEOUS ROOTS, STONES, CONCRETIONS, PERMEABILITY, ETC.
0	Reddish brown	sandy loam	breaks up into small clods.	loose when moist, hard when dry	moderately acid	permeable
12	reddish brown	loam	cloddy	slightly compacted	neutral	permeable
24	brownish red	clay	block	very compact	slightly basic	clay retards penetration of moisture and roots.
36	Brown to red		massive	Very dense	basic	Iron and silicia cemented hardpan Impermeable
48, 60	Brown	variable textured	structureless	loose to fairly compact	basic	permeable

Fig. 6.—Profile description of San Joaquin sandy loam, a typical hardpan soil of group IV.

GROUP V, STRONGLY WEATHERED SOILS WITH DENSE CLAY SUBSOILS RESTING ON CONSOLIDATED MATERIALS

Soils of group V are common along the coastal plain of California. Their value is relatively low because of the leached surface, the heavy-textured subsoil, and particularly because of the hardpan-like substratum which, although composed of sediments, is essentially rock-like in its nature (fig. 7). Surface soils are normally somewhat acid in reaction. There is usually an abrupt change from the surface layer to the heavy dense clay subsoil, and after heavy rains these soils become temporarily water-logged.

With two exceptions, the Stockton and Landlow, all the soil series so far mapped occur on high terraces which have been subjected to considerable erosion. The Stockton and Landlow soils occur on flat, poorly drained plains, and instead of being sandy have heavy-textured surface soils.

In this group the surface soils overlying the clay subsoils are usually less than 15 inches in thickness, and the clay subsoil varies from 10 to 24 inches in thickness. Thus the consolidated substratum is found at from 15 to 48 inches below the surface.

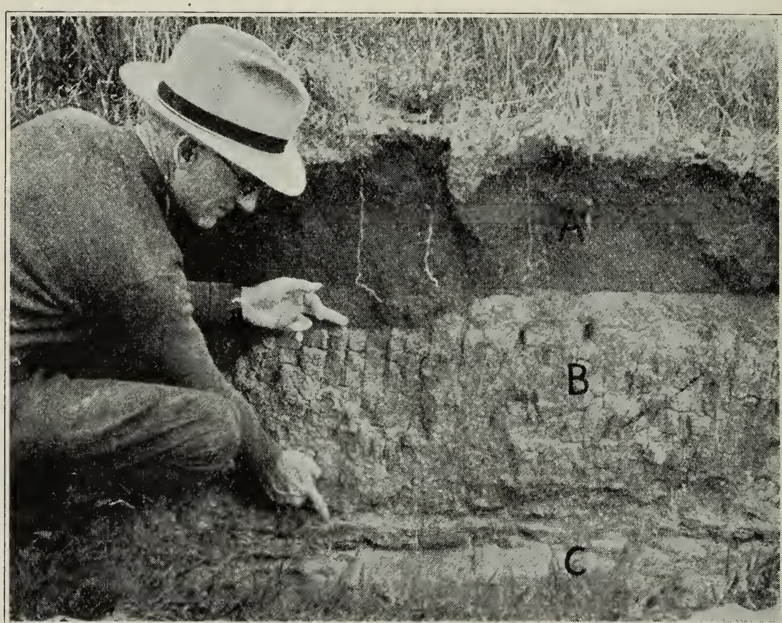
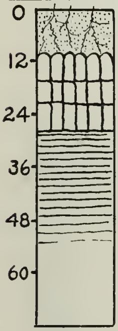


Fig. 7.—Profile of Olivenhain loamy fine sand from San Diego County, California. Note the sandy surface soil lacking structure, the heavy-textured, dense subsoil, which breaks up into columnar structure when dry, and the massive consolidated substratum. This is a typical soil of group V. (From Bul. 552.)

In rating the soils of this group for factor A the points considered are the depth to the clay layer, the depth to the substratum, the nature of the substratum, and the surface relief. The range in rating is from 20 to 40 per cent. Surface texture and other factors are handled under factors B and C.

Soils of the Olivenhain, Tierra, and Las Flores series, which are typical of this group, have similar sequence of horizons, and differ mainly in color. A profile of Olivenhain loamy fine sand from the coastal plain of San Diego County is given in figure 8. The factor-A rating of this soil is 25 per cent.

TYPE Olivenhain loamy fine sand LOCATION Thirty miles north of San Diego
RELIEF High eroded terrace ELEVATION 400 ft. DRAINAGE Subdrainage restricted
RAINFALL 6-12" NATIVE VEGETATION Short brush USE Shallow rooted crops.
ORIGIN Marine terrace DEVELOPMENT OF PROFILE Semi mature
REMARKS
Profile rating of 25



PROFILE	COLOR	TEXTURE	STRUCTURE	CONSISTENCE AND DENSITY	REACTION	MISCELLANEOUS ROOTS, STONES, CONCRETIONS, PERMEABILITY, ETC.
	Brown	loamy fine sand	slightly granular	loose	pH 6.2 slightly acid	few roots
	Dark brown	clay	Breaks up into columns when dry	very compact	7.2 slightly basic	Roots do not penetrate this layer very readily. High content of colloidal clay.
	Brown to light gray.	variable textured	massive	consolidated	7.0	Saline substratum

Fig. 8.—Profile description of Olivenhain loamy fine sand, typical of coastal plain soils having dense clay subsoils (group V).

GROUP VI, SOILS DEVELOPED ON BEDROCK (PRIMARY OR RESIDUAL SOILS)

Soils of group VI have been formed by the disintegration and decomposition of the underlying parent bedrock (fig. 9). Shaw[6] has termed them primary soils. They are also referred to in soil literature as residual soils. They are the hill lands of California, occupying a topography that is rolling, hilly, or mountainous (fig. 13).

Their characteristics are determined to a large extent by the character of the parent bedrock and the rainfall of the region in which they occur. Often they are shallow and stony. These factors, together with the topography and surface configuration, determine their value. Because of their slope, they are more difficult to farm than the terrace and valley lands. The steep slopes have a tendency to erode badly, especially when cultivated. The normal progress of erosion is the main factor that keeps most primary soils from reaching a mature stage of soil weathering. Most of the primary soils have a moderate accumulation of clay in the subsoils as a result of soil weathering, but not nearly so much as exists in soils of groups III, IV, or V. Usually the upper portion of the underlying parent bedrock has been softened by weathering action so that roots and moisture have an opportunity to work their way down into the bedrock through cracks and crevices for some distance.

[6] Shaw, C. F. A definition of terms used in soil literature. Intntl. Congr. Soil Sci. Proc. 5:38–64. 1928.

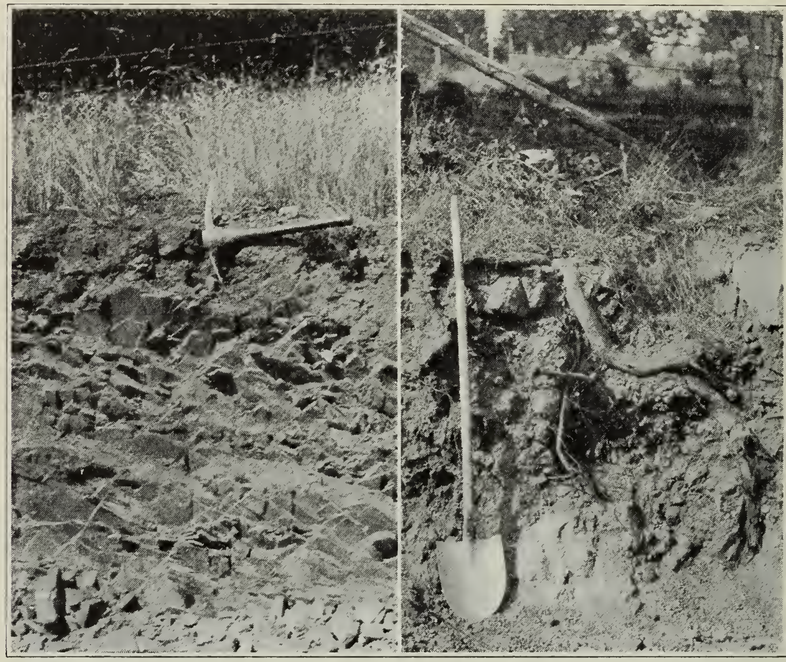


Fig. 9.—Profiles of shallow primary soil (group VI), Sierra Nevada foothill district.

TYPE *Holland sandy loam* LOCATION *Sierra Nevada foothills near Newcastle*
RELIEF *Hilly* ELEVATION *700 feet* DRAINAGE *Well drained*
RAINFALL *30 inches* NATIVE VEGETATION *Brush - oak* USE *Plums and peaches*
ORIGIN *Primary soil from granite* DEVELOPMENT OF PROFILE *Immature*
REMARKS
Profile rating of 65

PROFILE	COLOR	TEXTURE	STRUCTURE	CONSISTENCE AND DENSITY	REACTION	MISCELLANEOUS ROOTS, STONES, CONCRETIONS, PERMEABILITY, ETC.
0 12	Light grayish brown	sandy loam	coarse granular	friable, loose	moderately acid	permeated by roots
24	Light brown	sandy loam	breaks up into small clods	slightly compact	moderately acid	permeated by roots
36	Brown	gritty loam	medium sized clods	compact when dry	moderately acid	some colloidal glazing
48 60						Disintegrating granitic bedrock.

Fig. 10.—Profile description of Holland sandy loam in the Sierra Nevada foothills. This is a primary or residual soil of group VI.

Considerable variation is encountered in depth and stone content, and such variations are considered in rating these soils. Typically, primary soils are well drained and contain no alkali so that these factors do not have to be considered under factor C.

Texture of the surface soil is largely governed by the type of parent bedrock. Coarsely crystalline rocks, such as granites, usually give rise to sandy soils, while the finer-textured rocks, such as the andesites, weather into clay loam types.

Some of the better-known primary soils are those of the Holland, Sierra, and Aiken series of the Sierra-Nevada foothills. The Aiken is the very red primary soil derived mainly from andesitic parent bedrock, while the other two are brown and red granitic soils. A profile description of a Holland sandy loam of the Sierra-Nevada foothill district is given in figure 10.

The ratings given the primary soils are based on the depth of soil material overlying bedrock, as follows:

	Rating, in per cent
Less than 1 foot	20–25
1 to 2 feet	25–40
2 to 3 feet	40–60
over 3 feet	60–70

FACTOR B: TEXTURE OF SURFACE SOIL

Factor B rates the soil on the basis of the characteristics of the surface soils, independent of the subsoils. It is a rating of the soil textures and those other characteristics that are more or less dependent on texture, such as the consistence (hardness or softness) of the soil aggregates, the porosity of the soil mass, the permeability to water, the tilth (response to tillage operations), and similar characteristics or reactions. These are so dominated by texture that a rating on the textural basis will also express the general effect of these features.

Textural grades, designated in popular terms such as sandy loam, loam, and clay loam, express the mass effect of the amounts of different-sized grains that constitute the soil. The physical composition of a soil can be accurately determined by a mechanical analysis which separates the soil into grain-sized groups. The limits of the amounts of the grain-sized groups present in any textural grade have been definitely established.

TABLE 3

Textural Grades of Soils*

Grade	Definition†	Obvious characteristics
Coarse sand	Contains less than 20 per cent silt and clay, and more than 35 per cent fine gravel and coarse sand grain sizes, and less than 50 per cent any other grade.	Sands are loose and granular. The individual grains can readily be seen and felt. Squeezed in the hand when dry the material will fall apart when the pressure is released. Squeezed when moist, it will form a cast but will crumble when touched, although fine sand and very fine sand have a certain amount of cohesion when moist.
Sand	Contains less than 20 per cent silt and clay, and more than 35 per cent fine gravel and coarse sand and medium sand, and less than 50 per cent fine sand.	
Fine sand	Contains less than 20 per cent silt and clay, and more than 50 per cent fine sand, and less than 25 per cent fine gravel and coarse and medium sand.	
Very fine sand	Contains less than 20 per cent silt and clay, and more than 50 per cent very fine sand, and less than 25 per cent fine gravel and coarse and medium sand.	
Sandy loam	Contains between 20 and 50 per cent silt and clay, and more than 25 per cent fine gravel and coarse and medium sand, and less than 35 per cent fine or very fine sand.	Contains much sand but which has enough silt and clay for coherence, gritty feel; sand grains can be seen. Squeezed when dry will form a cast which will readily fall apart, but if squeezed when moist a cast can be formed that will bear careful handling without breaking. Classed as coarse, medium, fine or very fine sandy loam, depending on the proportion of the different-sized particles that are present.
Fine sandy loam	Contains between 20 and 50 per cent silt and clay, and more than 50 per cent fine sand, and less than 25 per cent fine gravel and coarse and medium sand.	
Very fine sandy loam	Contains between 20 and 50 per cent silt and clay, and more than 35 per cent very fine sand, and less than 25 per cent fine gravel and coarse and medium sand.	
Loam	Contains more than 50 per cent total silt and clay, and less than 20 per cent clay, from 30 to 50 per cent silt, and from 30 to 50 per cent sands.	Even mixture of different grades of sand, and of silt and of clay. Mellow, of somewhat gritty feel, yet fairly smooth and rather plastic. Squeezed when dry it will form a cast that will bear careful handling, while the cast formed by squeezing the moist soil can be handled rather freely without breaking.

* For ratings see table 4, page 38.

† The grades are defined on the basis of the amount of the several grain-sized groups of particles found in them upon mechanical analysis. For the sizes of the soil-particle groups see footnote 7, page 24.

TABLE 3—*(Concluded)*

Grade	Definition	Obvious characteristics
Silt loam	Contains more than 50 per cent total silt and clay, and less than 20 per cent clay, more than 50 per cent silt, and less than 50 per cent sands.	Moderate amount of the fine grades of sand and only a small amount of clay, over half of the particles being of the size called "silt." When dry it may appear cloddy but the lumps can readily be broken, and when pulverized it feels soft and floury. Either wet or dry the soil will form a cast that can be freely handled without breaking. If squeezed between the thumb and finger it will not "ribbon," but will give a broken appearance.
Clay loam	Contains more than 50 per cent total silt and clay, and 20 to 30 per cent clay, and less than 50 per cent silt or sand.	A clay loam in the field is dense and compact, and breaks into clods or lumps, which when dry are hard to break. When the moist soil is pinched between the thumb and finger it will form a thin "ribbon" that will break readily, barely sustaining its own weight. Moist soil is plastic and will form a cast that will bear much handling. When kneaded in the hand it does not crumble readily but tends to work into a heavy compact mass.
Silty clay loam	Contains more than 50 per cent total silt and clay, and 20 to 30 per cent clay, more than 50 per cent silt, and less than 30 per cent sand.	Silty clay loam contains more of the particles termed "silt" so that the soil is less plastic than the clay loam.
Clay	Contains more than 30 per cent clay, and less than 50 per cent silt or sands.	Dense and compact, forming very hard lumps or clods when dry. Composed of very fine particles which when wet stick together to make a very putty-like and plastic mass. When the moist soil is pinched out between the thumb and fingers it will form a long flexible "ribbon."
Silty clay	Contains more than 30 per cent clay, more than 50 per cent silt, and less than 20 per cent sands.	Silty clay contains more of the particles termed "silt" so that the soils break down more readily than a clay.
Adobe clay or clay adobe	Contains more than 30 per cent clay, particularly the ultra or colloidal-clay particles, and less than 50 per cent silt or sands.	In addition to characteristics of clay, adobe clays contract on drying, producing large cracks and blocks. Secondary cracking may cause them to break into smaller fragments. The term "adobe" alone, refers to this structure produced by shrinkage on drying.

The various textural grades of soils are listed in table 3, with the amounts of the grain-sized groups (determined by mechanical analysis),[7] and some of the obvious physical characteristics of the various soil textures. The major textural grades give very characteristic responses when rubbed between the thumb and fingers, and when kneaded and molded while wet. With practice, the textural grade of a soil can be approximated by this hand test, which aids in determining the texture when soil maps are not available.

Texture or physical composition controls, to a large degree, the water-holding capacity, permeability to moisture, ease of tillage, plasticity, the stickiness of the soil when wet, and the friability and hardness when dry. Soils having ideal conditions from the textural standpoint as reflected in these physical characteristics are rated at 100 per cent in factor B. Soils having less favorable textures are rated according to their relative order. Soils with a large percentage of sand or gravel are relatively low in the plant nutrients and do not retain moisture so well as do those of finer texture. At the other extreme heavy-textured soils, those having a high percentage of clay particles, are more difficult to handle and have other disadvantages, although they may contain a maximum of moisture and plant nutrients.

It must be borne in mind that the ratings on soil texture are on a *relative basis* and can be varied to some degree as conditions may warrant.

MEDIUM-TEXTURED SOILS	Rating, in per cent
Fine sandy loam	100
Loam	100
Silt loam	100
Sandy loam	95
Coarse sandy loam	90
Loamy sand	80

The medium-textured soils are given the highest rating since they do not contain an excess of either the sand or the clay, have a medium-soft consistence, take water readily yet have a good water-holding capacity, are friable and easy to cultivate, do not readily puddle or form clods, and in general are most easily maintained in a condition of good tilth.

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[7] Eight grain-sized groups have been adopted by the United States Department of Agriculture with the effective diameter of the particles as indicated below:

Diameter in millimeters	Name of size group	
2.0 – 1.0	fine gravel	
1.0 – 0.5	coarse sand	
0.5 – 0.25	sand	
0.25 – 0.10	fine sand	
0.10 – 0.05	very fine sand	
0.05 – 0.005	silt	
0.005 – 0.002	coarse clay	clay
less than 0.002	ultra or colloidal clay	clay

Fine sandy loam,[8] loam, and silt loam are given the highest textural rating. They have a fairly high water-holding capacity (18 to 40 per cent by dry weight), and a high amount of available water. These are the best-textured soils for such intensive crops as vegetables, which have to secure their moisture and plant nutrients from a relatively small volume of soil. Sandy loams are rated slightly lower since they do not have the power to hold as much moisture, and so do not have quite the range in use that the fine sandy loams, loams, or silt loams have.

Coarse sandy loams have a still lower water-holding capacity and usually less organic matter and plant nutrients, and so are rated lower than the sandy loams.

Loamy sands hold 5 to 9 per cent of moisture as against 10 to 13 per cent by sandy loams. For most crops they do not have as much potential value as the slightly heavier-textured soils even though they are easy to handle at any moisture content. They have a fairly high value for certain specialized crops that are grown along the coast, such as winter squash, peas, etc.

MEDIUM-HEAVY-TEXTURED SOILS	Rating, in per cent
Silty clay loam	90
Clay loam	85

Silty clay loam and clay loam soils have a high water-holding capacity (25 to 40 per cent), but puddle rather easily and have a tendency to become hard on drying. Their general range in cropping adaptation is lower than the loam or silt loam since they take water more slowly, are harder when dry, and more power is required in the use of tillage implements. Silty clay loam is somewhat easier to till than the clay loam because of the higher silt content. Certain calcareous types of both the silty clay loam and clay loam are more friable owing to the high lime content. As a general rule, soils of these textures are fertile and highly productive in California.

HEAVY-TEXTURED SOILS	Rating, in per cent
Silty clay	60
Clays and adobe clays	50–70

[8] In classifying the yields of oranges on different soil types in southern California, Vaile states that "the groves planted on medium-textured soil (fine sandy loam) gave the highest average yield." (Vaile, Roland S. Survey of orchard practices in the citrus industry of southern California. California Agr. Exp. Sta. Bul. **374**:11, table 6. 1924.) It is significant that only about 5 per cent of the groves were planted on very light soil (sand) and that these groves produced 30 per cent less than those on medium-textured soil, while only from 5 to 10 per cent of the groves were planted on medium-heavy soil and these produced 10 per cent less than those on the medium-textured soil.

The properties of silty clay and clay soils are largely governed by the character of the clay particles that make up from 30 to 60 per cent of the soil mass. Often a large proportion of the clay particles are of the ultra-clay or colloidal-clay size and exhibit the physical properties of colloids.

Clay soils are cold and sticky when wet, and very hard when dry. The high clay or colloidal content impedes the movement of water, causing water-logged conditions in wet weather and lack of available moisture during the dry season. When dry, they shrink and crack, frequently breaking into large, hard blocks with wide cracks between, giving the structure known as "adobe clays." As a result they are not so desirable as the lighter-textured soils. They are best adapted to crops, such as grain and rice, for which heavy machinery is needed.

Most clays are improved by the addition of lime or other flocculating materials, which cause the soil to form aggregates with definite structural properties, and results in a decrease in the plasticity and hardness of the mass. This materially increases the ease of tillage. On the other hand, certain of the alkali salts exert a deflocculating effect on the soil mass, making it less pervious and more difficult to till. Organic matter acts very much in the same way as lime on clay soils, but the amount has to be high and frequently applied in order to make much improvement in the physical condition.

Clays generally are high in plant nutrients, but physical factors such as plasticity, penetrability, and drainage overshadow these desirable chemical characteristics.

Silty clay is a little more friable owing to the higher content of silt.

LIGHT-TEXTURED SOILS	Rating, in per cent
Very fine sand	80
Fine sand	65
Sand	60
Wind-blown sands	20–70

The sands listed above differ in the relative size of the sand particles making up the soil. All have less than 20 per cent total silt and clay particles. The large proportion of sand particles renders these soils open and friable. Water percolation through the soil mass is fairly rapid and is liable to be excessive in the coarser sands. Air moves rapidly through sandy soils and they warm up more quickly in the spring than do heavier-textured soils. This factor renders them desirable for certain specialized truck crops.

The wide range in the rating of wind-blown sands—20 to 70—is due to the great variation in the surface configuration of this type of material. Soils of the Rositas, Coachella, and Oakley series are typical examples

of wind-blown material. The shifting of sand by wind action causes serious difficulties in certain instances. The cost of leveling this type of material for irrigation is relatively high.

The available plant nutrients of sands are low. Large applications of organic material in the form of manures or covercrops are necessary to maintain yields on them, and frequent application of fertilizers is necessary in order to maintain their value for intensive cropping. Moisture must be available at regular intervals during the growing season. This interval and application is necessarily relatively short since the moisture-holding capacity of the sands is small compared with that of the medium-textured soils. The normal moisture capacity will vary from 2–3 per cent in the coarse sand up to 7–10 per cent for the very fine sand. Thus it can readily be seen that the value decreases with the coarseness of the soil.

Sands occurring where there is a high rainfall are leached of their plant nutrients and are usually of very low productive value. Fortunately, the area of such soils in California is limited largely to the northern coast line. Some of the southern coastal plain sands have been moderately leached, but the arid and semiarid sands are fairly good producers when moisture and sufficient organic material are present.

GRAVELLY OR COBBLY SOILS	Rating, in per cent
Gravelly fine sandy loam	70
Gravelly loam	70
Gravelly silt loam	70
Gravelly sandy loam	65
Gravelly clay loam	55
Gravelly clay	35
Gravelly sand	20–30

The presence of gravel in a soil interferes with tillage operations, and, especially in the case of the lighter-textured soils, materially lowers their water-holding power. Suggested ratings are given above. These may have to be lowered or raised according to the amount of gravel present in the soil mass.

STONY SOILS	Rating, in per cent
Stony fine sandy loam	70
Stony loam	70
Stony silt loam	70
Stony sandy loam	65
Stony clay loam	60
Stony clay	35
Stony sand	10–40

Stone in a soil interferes with tillage and all farm operations, and lowers the water-holding capacity and the volume of actual soil from which plants can secure food. The rating of soils containing enough

stone to interfere with farm operations should be lowered. Suggested ratings are given above where the soils have been mapped under such type names in the soil surveys.

FACTOR C: SOIL-MODIFYING CONDITIONS

As mentioned previously, a number of other conditions may exist that modify the value of the soil. These are generally determined by field observations or by a few simple field tests. They are listed with suggested ratings under the following headings and in table 4 (page 38).

DRAINAGE

Soils having a high water table or a fluctuating ground-water level are obviously of lower value than those which are well drained. The past drainage history and the prospects of the soil's becoming water-logged under future utilization should have careful consideration in any system of soil evaluation. Many of the dark-colored alluvial soils are poorly drained, especially those at the lower ends of the alluvial fans where water has accumulated by seepage from the higher lands. Drainage conditions are divided into four classes, each given a rating.

1. Well Drained . . . . 100 per cent.—Soils are considered well drained where the water level is deep and there is no probability of the soil's becoming water-logged.

2. Fair Drainage . . . . 80–90 per cent.—Drainage is considered fair where the water table is sufficiently below the surface so that little crop injury is experienced, and where any excessive water can be taken care of through artificial drains at a low or moderate cost. Areas where there may be some shallow flooding for brief periods are also placed in this class.

3. Moderately Water-logged . . . . 40–60 per cent.—Soils are considered moderately water-logged where the permanent water table is sufficiently close to the surface so that only the shallow-rooted crops can be grown.

4. Badly Water-logged . . . . 10–40 per cent.—Land is considered badly water-logged where the ground water is permanently close to the surface, so that agriculture is limited to very poor wild grasses.

ALKALI

Alkali is often the limiting factor governing the value of desert soils. It consists of an excess of soluble salts that have accumulated in the soil because of poor drainage and excessive surface evaporation (fig. 11).

Chemically, they may be sodium chloride, sodium sulfate, sodium carbonate, etc. Alkali is not normal to humid soils of the eastern part of the United States since it cannot accumulate where there is a high rainfall and the soils are leached.

Recognizing the importance of alkali, careful studies are made of this problem in the soil surveys of desert areas. The harmfulness of alkali is dependent not only on the amount present in the soil, but on its position in the profile, its chemical composition, the texture of the soil, and the

Fig. 11.—White alkali crust, with a native cover of greasewood. This soil is of no value for agriculture because of the high alkali content. (Photograph by W. W. Weir.)

amount of moisture present. Plants do not tolerate a great deal of alkali if it is concentrated as a surface crust, or if it is of the "black" variety (sodium carbonate), or if it is concentrated in a dry soil.

In mapping the alkali of an area such lands have often been classed in four grades[9] with reference to the total content, the kind of alkali, and the visible conditions such as the appearance of the crop or the presence of alkali-tolerant weeds growing on the land (fig. 11).

1. Alkali-free: 100 per cent.—This grade includes areas whose salt content is less than 0.2 per cent and so evenly distributed throughout the soil profile as to be noninjurious to crops.

2. Slightly Affected Areas: 90 per cent.—This grade includes areas whose salt content is usually between 0.2 and 0.6 per cent, but so distributed throughout the soil profile as to have only slight effect on crops.

[9] Strahorn, A. T., *et al.* Soil survey of the El Centro area, California. U. S. Dept. Agr. Bur. Soils, pp. 641–716. 1918.

3. Moderately Affected Areas: 60 per cent.—This grade includes land with a salt content of less than 2 per cent, which is so distributed in the soil profile as to depress the yields of crops, but not prevent their growth. Soils with a much smaller amount of black alkali are rather toxic.

4. Strongly Affected Areas: 5–25 per cent.—Crops are limited and to a large degree prohibited by the alkali content in these areas. The total amount of salts may vary from 1 to 2 per cent or more, as an average throughout the profile, but is usually high in the surface foot—often over 3 per cent. Some of these areas have practically no value for agriculture. Soils with much smaller amount of black alkali (sodium carbonate) may be rather toxic and should be placed in this grade.

ACIDITY

A number of soils exist in California which are acid in reaction (table 1, page 7). The rating of acid soils is reduced according to the degree of acidity, for most crops are injured by excessive acidity of the soil. Suggested ratings vary between 60 and 95 per cent. The hydrogen-ion concentration (usually expressed as pH) of soils is a measure of the intensity of acidity. Soils with a pH of about 7.0 are said to be neutral in reaction; those with a pH of 6.0–6.5, slightly acid; those with a pH of 4.5–6.0, moderately acid; and those with a pH below 4.5, very acid. Alkaline soils have a pH of over 7.0. Soil acidity can be quickly and easily determined by simple tests. A number of field testing kits, satisfactory for approximate determinations of soil reaction, are available.

INFERTILITY

Information can usually be secured about the general fertility of a soil by studying the past cropping history. Where a soil is of lowered fertility, its rating can be lowered by applying a factor here to take care of this. In most cases this will be between 80 and 95 per cent, although in some extreme cases a lower number should be given.

A routine chemical analysis does not give very much information regarding the adaptability of soils to crops, or methods of fertilization,[10] so that field observations on the cropping history and the native vegetation growing on the soil must be used to supplement other information regarding the availability of plant nutrients. Often valuable information can be secured by studying the distribution of crops on each soil series or soil type. Where agriculture has been long established in a re-

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[10] Hoagland, D. R. Fertilizer problems and analysis of soils in California. California Agr. Exp. Sta. Cir. 317:1–16. 1930.

gion this information is of great value in rating the productive capacity of the respective soils. "Worn out" or infertile soils can be determined by such a study.

STRATIFIED SUBSOILS (GRAVELLY LAYERS OR STRATIFIED CLAY LAYERS)

Where moisture is a limiting factor in crop growth, the presence of gravelly layers in the alluvial soils is a distinct handicap, since such subsoils are of leachy character with little power of holding moisture for crop use. These gravelly pockets, or subsoil layers, are most common in soils of the Tujunga, Hanford, Yolo, and Elder series, which are of fairly recent deposition. Such pockets are a result of the deposition of gravelly material by fast-moving water, and later deposition of finer and better surface soil over it. These "pockets" are not obvious from surface soil examination, except that crops may appear wilted where there is a deficiency of moisture. The rating given soils having such conditions will naturally vary, although a rating of 80–95 per cent will take care of most cases.

Certain alluvial soils having heavy-textured layers in the subsoils should be discounted in value to some extent. Fairly large areas of soils having such conditions exist in the Imperial Valley. A rating of 80–95 per cent is suggested to cover such conditions.

SHALLOW PHASES OF ALLUVIAL SOILS

In certain extreme cases alluvial soils may be only 2 or 3 feet deep over a flat substratum or bedrock. A rating of 50–60 per cent might be given for a 2-foot depth of soil, and a rating of approximately 70 per cent for alluvial soils about 3 feet in depth.

ERODED SOILS

All soils located on slopes erode or wash to some extent. Under certain conditions of rainfall and removal of the vegetative cover by cultivation, overgrazing, lumbering, and fire, this is hastened, and the soils erode to such an extent that their value is materially lowered[11] (fig. 12). Soils eroded to a moderate extent might be given a rating of 80–95 per cent, while the badly eroded soils, such as those mapped as eroded phases, should be given a much lower figure.

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[11] Weir, Walter W. Soil erosion in California: its prevention and control. California Agr. Exp. Sta. Bul. 538:45. 1932.

STEEP PHASES

Soils occurring on steep slopes are difficult to till, and should be lowered in their rating. Rough mountainous slopes are of still less value. A range in the rating may be 60–80 per cent for soils occurring on slopes that are fairly difficult to till, and 20–30 per cent for soils on steep mountainous slopes.

Fig. 12.—Recent erosion cuts 2 to 3 feet in depth have materially lowered the value of this field. Note deposition of eroded soil material on the flat. (From Bul. 538.)

NONAGRICULTURAL MATERIALS

In most of the soil surveys there is a miscellaneous class of materials that is not classed with the soil series or soil types, but classed under a miscellaneous group. This has little value from an agricultural standpoint. For purposes of rating them, these are given an *index,* although they really belong in a system of land classification rather than in a soil category.

Nonagricultural materials which are mapped under miscellaneous group in soil surveys are as follows:

1. Rough Mountainous Land: 5–10 per cent.—This class of land usually occurs on rougher mountainous topography; it is often good grazing land (fig. 13).

2. Scabland: 5 per cent.—Scabland consists of fairly recent lava flows; contains small patches of soil (fig. 14); it is of very little agricultural value even for grazing.

Rough Broken Land: 5 per cent.—Rough broken land consists of steep slopes, eroded slopes, gullies, and canyon walls, and contains very small areas of arable land.

3. Riverwash: 1–5 per cent.—Riverwash consists of sandy, gravelly, cobbly, or stony deposits of stream channels; subject to erosion and overflow; of no agricultural value.

Fig. 13.—Rough mountainous and rough stony land. Note small cleared area of primary soil (group VI soils). (From Bul. 552.)

Fig. 14.—Scabland: a very thin layer of soil weathered from fairly recent lava flow. It is of very low value. (Photograph from C. F. Shaw.)

Placer Diggings and Tailings: 1–5 per cent.—Areas where placer-mining operations have left the surface covered with stone and gravel are placed in this class.

Tidal Marsh: 1–5 per cent.—Tidal marsh lands are lands subject to inundation by tidal action; they are low, flat, and highly saline.

Coastal Beach: 1–5 per cent.—This class applies to sloping beaches of sand, gravel, or stone.

Dunesand: 1–5 per cent.—Dunesand consists of areas of sand on dunes or ridges; in more or less constant movement with wind.

Rough Stony Land: 1–5 per cent.—This class includes rough, stony slopes (fig. 15). The presence of excessive amounts of stone and large rocks or boulders is the dominant factor.

CALCULATION OF THE INDEX

To use this index method for rating soils it is obviously necessary to know the characteristics of the soils to be rated. This information may be obtained directly by adequately exploring the soil and subsoil to a depth of 6 or more feet throughout the whole area to be rated, supplementing this exploration by field and laboratory studies to determine the less obvious characteristics of the soil. This would require much time and patient investigation, as well as a considerable degree of training in soil studies. Most of the needed information can be obtained from the soil maps and reports if the area to be rated has been covered by the soil survey. The information available in these surveys has already been discussed to some extent, and the Appendix gives further information and lists the areas on which surveys have been completed and are available.

As the soil maps are usually published on the scale of 1 inch to the mile, it is difficult to show on the maps soil bodies that are less than 5 acres in area. Hence in rating any area it is essential that the information supplied by the soil surveys be supplemented by direct field examination to ascertain the less extensive and more intimate characteristics of the soils, and particularly the conditions included in factor C.

From experience in the use of the index it is suggested that the sequence given herewith be followed.

1. Ascertain the characteristics of the soil profile and especially those of the subsoil and substratum, from soil-survey data and field studies. Determine the group in which the soil belongs and develop the rating for factor A.

2. Ascertain the textural characteristics of the surface soils, checking by careful field observations to determine the direction of any local variation from the typical texture. From these studies develop the rating for factor B.

3. Ascertain the presence or absence of alkali, poor drainage, or other soil-modifying conditions. These are more variable in occurrence and extent than the characteristics that determine factors A and B, and re-

quire much more field investigation to determine the intensity of local conditions. From the results of this study, develop the rating for factor C. Unless some specific unfavorable factor is present, the rating for factor C should be 100 per cent.

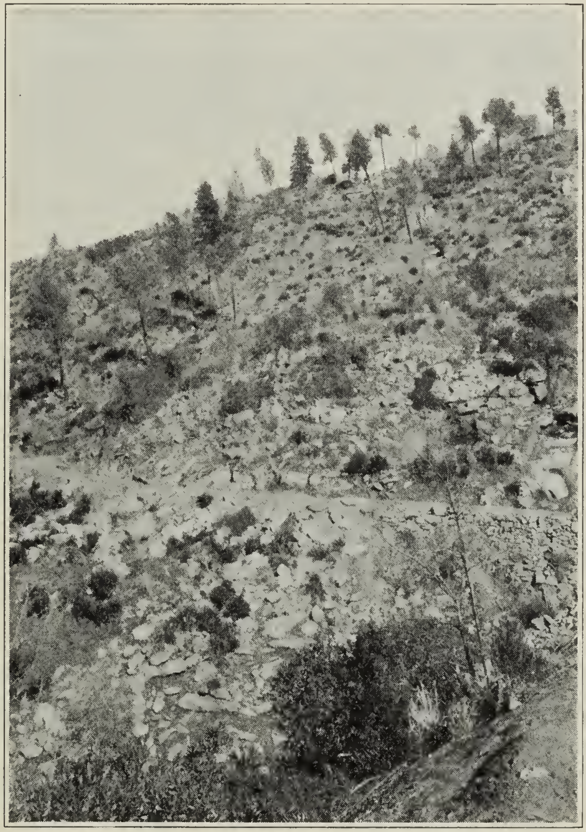

Fig. 15.—Rough stony land, nonagricultural class. It supports growth of brush and a few trees. (Photograph by C. F. Shaw.)

The final soil index is then obtained by multiplying A times B times C. The values and limits assigned to the several divisions of each of the three factors are summarized in table 4 (page 38).

SOIL RATING FOR A TRACT OF LAND

When a tract of land is to be rated, the soil survey, if available, is consulted, and a field examination is made. On the basis of these, a soil map such as that shown in figure 16 is prepared. The index for each soil type in the tract is calculated separately, and then a rating for the entire

tract is calculated by weighting each soil index according to the proportion of the acreage of that soil in the tract. Various tracts of land can be compared by the use of these figures.

For the tract shown in figure 16, the steps in calculation would be as follows:

1. Index for Hfsl, Hanford fine sandy loam: This soil is granitic fine sandy loam of alluvial origin with no compaction or clay accumulation in the subsoil, more than 6 feet in depth, well drained, and has no alkali. It is of high productive value.

	Rating, in per cent
Factor A: Hanford Series, group I	100
Factor B: fine sandy loam (medium-textured soil)	100
Factor C: has no other modifying soil factors	100

$$\textit{Index rating} = \overset{A}{100\%} \times \overset{B}{100\%} \times \overset{C}{100\%} = 100\%$$

2. Index for CSiCl, Chino silty clay loam: This is dark gray alluvial soil of granitic origin, with gray to dark gray subsoils which are calcareous. The soil is more than 6 feet in depth, but has a water table at a depth of 3 feet from the surface.

	Rating, in per cent
Factor A: Chino Series, group I	100
Factor B: silty clay loam (medium heavy)	90
Factor C: moderately water-logged	60

$$\textit{Index rating} = \overset{A}{100\%} \times \overset{B}{90\%} \times \overset{C}{60\%} = 54\%$$

3. Index for Hstl, Holland stony loam: This is brown primary soil from granitic parent material. Bedrock is at an average depth of 3 feet. A considerable number of stones occur throughout soil mass. The surface is gullied to some extent.

	Rating, in per cent
Factor A: Holland Series, group VI (depth 3 feet)	60
Factor B: stony loam (stony)	70
Factor C: eroded surface	80

$$\textit{Index rating} = \overset{A}{60\%} \times \overset{B}{70\%} \times \overset{C}{80\%} = 33\%$$

4. Index for R, rough stony land: The area consists of extremely stony slopes, and is of little value.

$$\textit{Index rating} = 2\%$$

5. The index for the entire tract shown in figure 16 may then be calculated according to the acreage of each soil, as follows:

Soil	Index		Acreage		
Hanford fine sandy loam	100	×	95	=	9,500
Chino silty clay loam	54	×	10	=	540
Holland stony loam	33	×	65	=	2,145
Rough stony land	2	×	30	=	60
Total			200		12,245

$$\text{Tract rating} = \frac{12{,}245}{200} = 61.$$

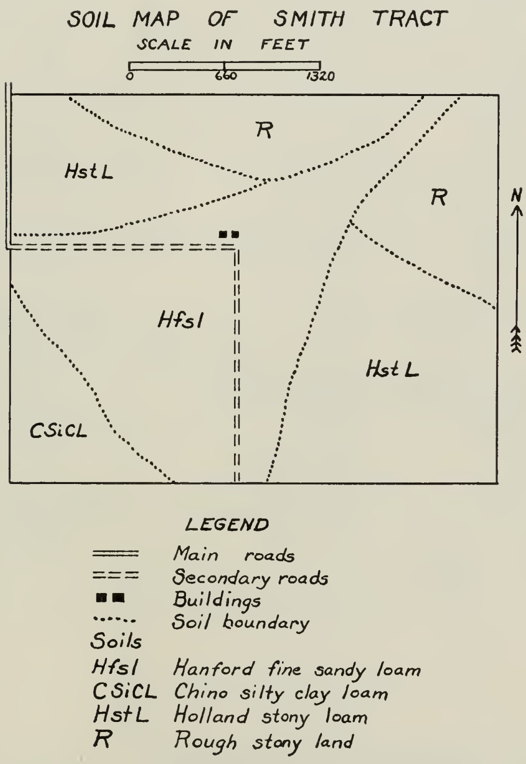

Fig. 16.—Soil map of a tract of land, which is made by field examination. The figures listed below give the types, their acreage, index, and grading.

Types	Acreage	Index	Grade
Hanford fine sandy loam	95	100	1—Excellent
Chino silty clay loam	10	54	3—Fair
Holland stony loam	65	33	4—Poor
Rough stony land	30	2	5—Very poor, non-agricultural

TABLE 4

SOIL RATING CHART—FOR RATING OR JUDGING THE AGRICULTURAL VALUE OF SOILS
(Soil Index Rating = Factor A × Factor B × Factor C)

Factor A, Rating of soils on basis of character of profile

Soil group	Rating, in per cent
I. Unweathered or slightly weathered secondary soils	95–100
II. Moderately weathered secondary soils	80–95
III. Strongly weathered secondary soils with dense clay subsoils, developed on unconsolidated parent material	40–80
IV. Maturely weathered secondary soils with hardpan:	
Hardpan less than 1 foot	5–10
1–2 feet	10–20
2–3 feet	20–30
3–4 feet	30–40
4–6 feet	40–60
V. Strongly weathered soils having dense clay subsoils resting on consolidated material	20–40
VI. Primary soils underlaid by bedrock:	
Depth less than 1 foot	20–25
1–2 feet	25–40
2–3 feet	40–60
Over 3 feet	60–70

Factor B, Rating of soils on basis of surface texture

Texture	Rating, in per cent
Medium-textured:	
fine sandy loam	100
loam	100
silt loam	100
sandy loam	95
coarse sandy loam	90
loamy sand	80
Medium-heavy textured:	
silty clay loam	90
clay loam	85
Heavy-textured:	
silty clay	65
clay and adobe clay	50–70
Light-textured:	
very fine sand	80
fine sand	65
sand	60
wind-blown sand	20–70
Gravelly or cobbly:	
gravelly fine sandy loam	70
gravelly loam	70
gravelly silt loam	70
gravelly sandy loam	65
gravelly clay loam	55
gravelly clay	35
gravelly sand	20–30
Stony:	
stony fine sandy loam	70
stony loam	70
stony silt loam	70
stony sandy loam	65
stony clay loam	60
stony clay	35
stony sand	10–40

Factor C, Rating of conditions and characteristics of the soil which modify its suitability for utilization in plant production

Condition	Rating, in per cent
Drainage:	
well drained	100
fair drainage	80–90
moderately water-logged	40–60
badly water-logged	10–40
Alkali:	
alkali free	100
slightly affected	90
moderately affected	60
strongly affected	5–25
Acidity:	
according to degree	60–95
Infertility:	
according to degree	60–95
Stratified subsoils	60–95
Shallow phases of alluvial soils:	
2 feet deep	50–60
3 feet deep	70
Eroded soils:	
moderate	80–95
badly	30–80
Steep phases:	
fairly steep	60–80
steep	20–30

Miscellaneous nonagricultural material

Type	Description	Rating in per cent
Rough mountainous land	Rough mountainous topography	5–10
Scabland	Recent lava flows	5–10
Rough broken land	Steep slopes, eroded slopes, gullies, and canyon walls	5–10
Riverwash	Deposits of stream channels	1– 5
Placer diggings and tailings	Piles of stone and gravel	1– 5
Tidal marsh	Tidal lands	1– 5
Coastal beach and dunesand	Sloping beaches of sand, gravel	1– 5
Rough stony land	Rough stony slopes	1– 5

SUMMARY

Soils vary in their productive capacity.

There is need for some method of comparing the relative productive capacity of different soils, especially in California where such a large number of widely divergent soil conditions exist. Such a soil rating or index would be useful in land classification and land evaluation.

In this paper the term "index for rating soils" is used to express this relative rating. Soils having the highest productive capacity (from a study of the soil under field conditions) are rated at 100 per cent.

The rating is based on the study of three general factors: A, character of the soil profile; B, texture; and C, modifying conditions.

Index numbers are used for each group of factors based on 100 per cent expressing ideal conditions.

The characteristics listed under factor A, character of the soil profile, are essentially those that determine the soil series. A grouping of the soil series of California is given according to their position in the six groups on the basis of factor A. Factors A and B together make up the soil type.

Characteristics listed under factor C, modifying conditions, consist of drainage conditions, alkali, etc.

The index is the product of the ratings given each of these three factors, $A \times B \times C$, the ratings and the final index being expressed in percentages.

By the use of this method of rating soils, a large number of divergent types can be compared, or various tracts of land can be compared from the soil standpoint.

The index for rating the agricultural value of soils presented in this bulletin can be used as a basis for judging soils.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance and advice of Professor C. F. Shaw and Professor W. W. Weir in the preparation of this paper. Helpful suggestions were also made by Mr. J. H. Keith, County Assessor of Riverside County.

LIST OF SELECTED REFERENCES

For the information of those who wish to secure more specific soil data, the following short list of books, bulletins, and circulars will be found to contain valuable information. In addition to those listed below, many other good books and publications are available, but the publications listed below will be found of particular use to those who do not find time for extended reading on this subject. Practical information on California soils can also be secured by consulting papers published in the American Journal of Agronomy, Proceedings of the American Soil Survey Association, Soil Science, and other similar publications.

EMERSON, PAUL.
1930. Principles of soil technology. vii + 402 p. Macmillan and Company, New York.

HARRIS, F. T.
1920. Soil alkali, its origin, nature and treatment. vii + 258 p. John Wiley and Sons, New York.

HIBBARD, P. L.
1931. Commercial fertilizers and soil fertility in California. California, Agr. Ext. Cir. **57**:1–37.

HILGARD, E. W.
1912. Soils. iii + 593 p. Macmillan and Company, New York.

HOAGLAND, D. R.
1930. Fertilizer problems and analysis of soils in California. California Agr. Exp. Sta. Cir. **317**:1–16.

POWERS, W. L., and T. A. H. TEETER.
1922. Land drainage. iii + 270 p. John Wiley and Sons, New York.

ROBINSON, G. W.
1932. Soils, their origin, constitution and classification. An introduction to pedology. vii + 390 p. D. Van Nostrand Company, New York.

SHAW, C. F.
1927. Definition of terms in soil literature. Proc. 1st Intntl. Congr. Soil Sci. **4**:38–64.
1927. The basis of classification and key to the soils of California. Proc. 1st Intntl. Congr. Soil Sci. **4**:65–104.
1927. Profile development and the relationship of soils of California. Proc. 1st Intntl. Congr. Soil Sci. **4**:291–318.

UNITED STATES DEPARTMENT OF AGRICULTURE.
Soil survey reports and maps (for the area in which the reader is interested.)[12]

WEIR, WALTER W.
1932. Soil erosion in California: its prevention and control. California Agr. Exp. Sta. Bul. **538**:1–45.

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12 See Appendix for soil surveys completed in California.

APPENDIX: SOIL SURVEY DATA IN CALIFORNIA

There are two general types of soil surveys, the reconnoissance and the detailed, that cover portions of California. The extent of these surveys is shown on the map in figure 17. Reconnoissance surveys (shown on the insert in fig. 17) are generalized soil surveys with maps made on the scale of 1 inch to 2 miles or 1 inch to 4 miles. Seven such surveys were made during the period between 1913 and 1917, covering the major portion of southern California, the Sacramento and San Joaquin valleys, and the San Francisco Bay region. These show the soils in rather inclusive groupings and rarely show bodies of soil less than 160 acres.

They are being supplanted as rapidly as facilities permit by detailed soil surveys with maps made on the scale of 1 inch to 1 mile. On these maps the bodies of soils as small as 5 or 10 acres in extent are shown. All the soil maps are accompanied by reports giving a full description of the soil types shown with a discussion of their geographical distribution, relationship, and general utilization in that particular area. Where alkali is present to any extent a separate alkali map is published. In addition to the soil discussion, separate chapters are written covering the general description of the area, the climate, the agriculture, and often separate chapters on irrigation, drainage, and alkali conditions are included. In recent publications, there is also a technical discussion of the soils.

These soil surveys serve as an inventory of the soil resources of the state and as a background for soil classification, soil evaluation, and other studies. Before extensive studies can be made on individual soil series or soil types, it is necessary to know in detail the characteristics of these soils, and also the location, the general environment, and the extent of their occurrence. Basic studies on individual soil series or on groups of soil series are now in progress and in due time this soil information will become available in printed form.

Completed soil surveys available in printed form are listed in table 5, those out of print in table 6, and those completed but not yet published in table 7.

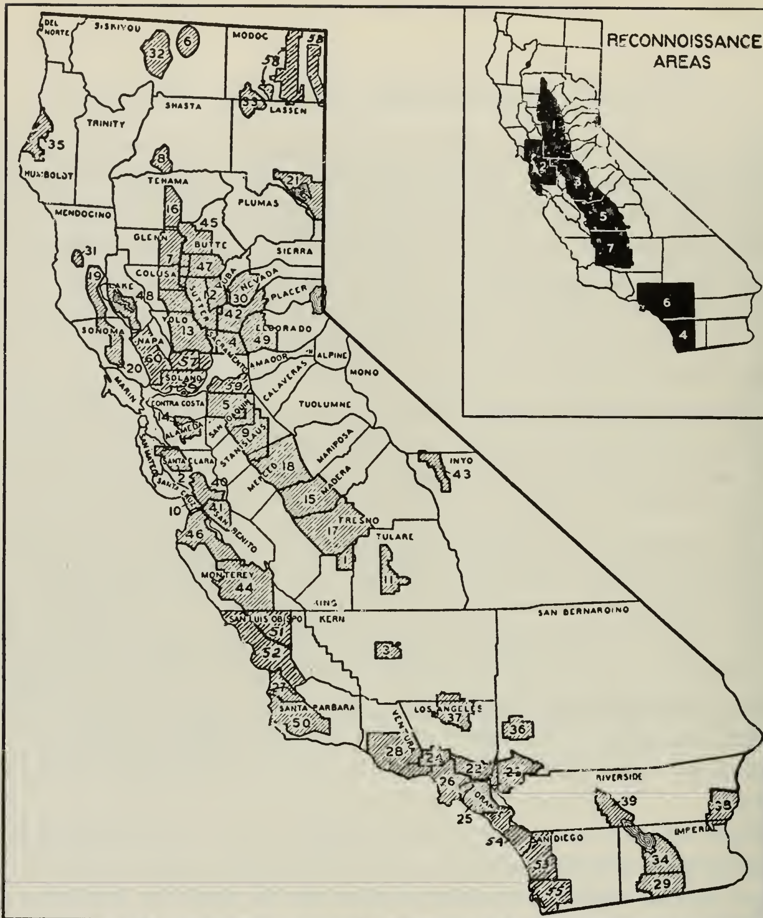

Fig. 17.—Soil-survey areas in California shown by shading:

1. Hanford
2. San Jose
3. Bakersfield
4. Sacramento
5. Stockton
6. Butte Valley
7. Colusa
8. Redding
9. Modesto-Turlock
10. Pajaro Valley
11. Porterville
12. Marysville
13. Woodland
14. Livermore
15. Madera
16. Red Bluff
17. Fresno
18. Merced
19. Ukiah
20. Healdsburg
21. Honey Lake
22. Pasadena
23. Riverside
24. San Fernando
25. Anaheim
26. Los Angeles
27. Santa Maria
28. Ventura
29. El Centro
30. Grass Valley
31. Willits
32. Shasta Valley
33. Big Valley
34. Brawley
35. Eureka
36. Victorville
37. Lancaster
38. Palo Verde
39. Coachella Valley
40. Gilroy
41. Hollister
42. Auburn
43. Bishop
44. King City
45. Chico
46. Salinas
47. Oroville
48. Clear Lake
49. Placerville
50. Santa Ynez
51. Paso Robles
52. San Luis Obispo
53. Oceanside
54. Capistrano
55. El Cajon
56. Suisun
57. Dixon
58. Alturas
59. Lodi
60. Napa

TABLE 5

Soil Surveys Available in Pamphlet Form, 1932*

Number as shown on map (fig. 17)	Area	Date of survey	Number as shown on map (fig. 17)	Area	Date of survey
25	Anaheim	1916	47	Oroville	1926
42	Auburn	1923	38	Palo Verde Valley	1922
33	Big Valley	1920	22	Pasadena	1915
43	Bishop	1924	49	Placerville	1926
34	Brawley	1920	23	Riverside	1915
45	Chico	1925	46	Salinas	1925
48	Clear Lake	1927		San Diego Reconnoissance	1915
39	Coachella Valley	1923	24	San Fernando	1915
29	El Centro	1918		San Francisco Bay Reconnoissance	1914
35	Eureka	1921	50	Santa Ynez	1927
40	Gilroy	1923	27	Santa Maria	1916
30	Grass Valley	1918	32	Shasta Valley	1919
41	Hollister	1923		Central-Southern California Reconnoissance	1917
21	Honey Lake	1915		Upper San Joaquin Reconnoissance	1917
44	King City	1924	28	Ventura	1917
37	Lancaster	1922	36	Victorville	1921
26	Los Angeles	1916	31	Willits	1918
	Lower San Joaquin Reconnoissance	1915	13	Woodland	1909
	Middle San Joaquin Reconnoissance	1916			

* Can be secured from the Division of Soil Technology, University of California, Berkeley, California.

TABLE 6

Soil Surveys No Longer Available for Free Distribution, 1932*

Number as shown on map (fig. 17)	Area	Date of survey	Number as shown on map (fig. 17)	Area	Date of survey
3	Bakersfield†	1904	9	Modesto-Turlock†	1908
6	Butte Valley	1907	10	Pajaro Valley	1908
7	Colusa	1907	11	Porterville†	1908
	Fresno†	1900	8	Redding	1907
17	Fresno†	1912	16	Red Bluff	1910
1	Hanford†	1901	4	Sacramento	1904
20	Healdsburg	1915		Sacramento Valley Reconnoissance	1913
	Imperial†	1901		San Bernardino†	1904
	Imperial†	1903		San Gabriel†	1901
	Indio†	1903	2	San Jose†	1903
	Klamath Reclamation	1908		Santa Ana†	1900
14	Livermore Valley†	1910	5	Stockton†	1905
	Los Angeles†	1903	19	Ukiah	1914
	Lower Salinas Valley	1901		Ventura†	1901
15	Madera†	1910		Yuma	1904
12	Marysville	1909			
18	Merced†	1914			

* May be consulted at the principal public libraries in bound volumes of the Annual *Field Operations of the Bureau of Soils.*

† Covered by more recent surveys.

TABLE 7

Soil Surveys Completed But Not Yet Published, 1932

Number as shown on map (fig. 17)	Area	Date of survey	Number as shown on map (fig. 17)	Area	Date of survey
51	Paso Robles	1928	56	Suisun	1930
52	San Luis Obispo	1928	57	Dixon	1931
53	Oceanside	1929	58	Alturas	1931
54	Capistrano	1929	59	Lodi	1932
55	El Cajon	1929	60	Napa	1932

13*m*-9,'33